International Civil Aviation Organization

THE FOURTH MEETING OF MODE S DOWNLINKED AIRCRAFT PARAMETERS WORKING GROUP (MODE S DAPs WG/4)

Web-conference, 29 – 31 March 2021

Agenda Item 3: Sharing of State's implementation on Mode S and related issues, including the experience in Mode S Interrogator Identifier (II) Code usage in APAC region

GUIDANCE MATERIAL FOR ASSIGNMENT OF INTERROGATOR CODES (IC) FOR MLAT AND ADS-B

(Presented by Singapore)

SUMMARY

During the Mode S DAPs WG/2, it was discussed whether interrogators that come with ADS-B need to be assigned with a distinct IC. Current practices suggested that II=0 can be used. However, the existing provision in ICAO documents is not clear to the reader and can be confusing. The Surveillance Panel Aeronautical Surveillance Working Group is working on revising the text in the SARPS and guidance material. The paper gives a preview of the proposed changes.

1. INTRODUCTION

1.1 Mode S interrogators required an assignment of Interrogator Codes (IC). Such IC could either be Interrogator Identifier Codes (II Code) or Surveillance Identifier Codes Codes (SI Code).

1.2 Mode S radars make use of ICs to reduce the need for aircraft to reply unnecessarily, by means of lock-out protocol. This is to help reduce frequency congestion. Due to this purpose of locking out in Mode S radar operations, radars with overlapping coverage do not share the same ICs. The assignment of ICs is to be coordinated within regions by centralised coordinating bodies (e.g. Eurocontrol for Europe and ICAO APAC for the case of Asia-Pacific).

1.3 It was recalled that during Mode S DAPs WG/2, there was a discussion on such interrogators that come with ADS-B stations need to be assigned with a distinct IC.

1.4 The ICAO Surveillance Panel (SP) Aeronautical Surveillance Working Group (ASWG) has been informed in Sep 2019 on the lack of guidance material relating to this issue. This paper provides a preview on the proposed changes to the SARPS and guidance material.

2. DISCUSSION

2.1 Annex 10 Volume IV is not very clear on which values could be used in the IIS field of selective interrogations transmitted by interrogators not using Mode S all-call interrogations, not using the lockout command neither the multisite data-link protocols.

2.2 It is proposed to clarify the usage of IC code and IIS field. Enclosured is the latest paper from the Technical Sub-group of the AWSG that addresses clarification on the use of II = 0, need for coordination for IC codes and other changes relating to Mode A/C/S all-call. The paragraphs below briefly describes some proposed changes.

2.3 Section 3.1.2.5.2.1.2.3 of Annex 10 Vol 4 states that II Code = 0 **shall only be used** for supplementary acquisition in conjunction with acquisition based on lockout override. Although it is in a section about all-call interrogations (3.1.2.5.2.1 *Mode S-only all-call interrogation, uplink format 11)* it is proposed to change it and to remove the restriction to avoid the confusion with the use of II=0 in the interrogations transmitted by MLAT interrogators.

> 3.1.2.5.2.1.2.3 *II: Interrogator identifier*. This 4-bit value shall define an interrogator identifier (II) code. These II codes ~~shall be~~ are assigned to interrogators in the range from 0 to 15.~~ The II code value of 0 shall only be used for supplementary acquisition in conjunction with acquisition based on lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5).~~ When ~~two~~ multiple II codes are assigned to one interrogator only, one II code shall be used for full data link purposes.
>
> *Note 1.— Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.*
> *Note 2.— Lockout on the II code value of 0 is used for non-selective all-call lockout (3.1.2.6.9.2). It is not used for multisite all-call lockout (3.1.2.6.9.1).*

2.4 Amendments were made to show that there is no need of coordination for interrogators not using lockout or multisite datalink protocols. Coordination of IC codes may help aid understanding of RF contribution.

> 3.1.2.6.1.4.1 Subfields in SD. The SD field shall contain information as follows:
>
> a) If DI = 0, 1 or 7:
>
> IIS, the 4-bit (17-20) interrogator identifier subfield shall contain an identifier code of the interrogator (3.1.2.5.2.1.2.3).
>
> *Note .— The IIS is intented to match the II code used by the interrogator in the Mode S-only all-call interrogation (3.1.2.5.2.1). Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol, or multisite datalink protocol can use any IC in the IIS fields of their selective interrogations without coordination with neighbouring systems. The use of coordinated values differentiates interrogations transmitted by the different systems operating in the same area and facilitates the understanding of their respective contribution to the 1090 MHz environment.*
>
> 3.1.2.11.6 *Lockout coordination.* A Mode S interrogator shall not be operated using all-call lockout until coordination has been achieved with all other operating Mode S interrogators having any overlapping coverage volume in order to ensure that no interrogator can be denied the acquisition of Mode S-equipped aircraft.
>
> *Note 1.— This coordination may be via ground network or by the allocation of ~~interrogator identifier (II) codes~~ ICs and will involve regional agreements where coverage overlaps international boundaries.*

Note 2.— Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol, or multisite datalink protocol can use any IC value in the IIS or SIS fields of their selective interrogations without a need for coordination with neighbouring systems.

2.6 Doc 9924 Aeronautical Surveillance Manual

Section 4 of Appendix M of Doc 9924 states that a Multilateration system is basically a passive system but it may use interrogations to achieve a certain level of performance. The document however does not mention the code to be used. The text is proposed to be improved as follows:

4. MLAT

4.1 Multilateration (MLAT) ~~is basically a passive system but it~~ systems may use interrogations to achieve a certain level of performance~~. Active WAM systems can be used in approach and en-route environments.~~; however, care must be exercised to limit ~~the~~ interrogations, primarily to minimize transponder occupancy. ~~In such cases, s~~Selective interrogations transmitted by active systems have ~~the dominant~~an an important effect on ~~the~~ transponder availability because of the use of omnidirectional antennas. MLAT systems do not use Mode S all-call interrogations, lockout protocol, or multisite protocol. Therefore, they can use any IC in the IIS or SIS field of their selective interrogations, as it will not interfere with other interrogators using these protocols.

4.2 Significant levels of ~~ACAS~~ interrogations may reduce the transponder availability to a point that roll-call retries start to become a significant factor. However, this will be mitigated by a dynamic ~~active~~ WAM, which could abate roll-call in the presence of ~~ACAS~~ passive reception of ~~ACAS~~ altitude reports.

3. ACKNOWLEDGEMENTS

3.1 This is acknowledge the efforts of Mr Eric Portier from Eurocontrol and Mr Jack Field from MITRE for working the change proposal.

4. ACTION BY THE MEETING

4.1 The meeting is invited to note the status of the amendments to the SARPS and guidance material for assignment of IC to interrogators.

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ASWG TSG WP12-13R1
1 February 2021

International Civil Aviation Organization

WORKING PAPER

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)
SURVEILLANCE PANEL (SP)

AERONAUTICAL SURVEILLANCE WORKING GROUP (ASWG)
TECHNICAL SUBGROUP MEETING 12

1 February through 5 February 2021

II/SI Codes for Lockout Override, Supplementary Acquisition, and Non-All-Call Acquisition

(Prepared and presented by **Jack Field**)

SUMMARY

This paper provides proposed changes to the SARPs related to lockout override and supplementary acquisition. Lockout override should be permitted on any interrogator code (IC), as the transponder will disregard the IC. Supplemental acquisition, which is limited by definition, should also be allowed on any IC. Finally, an interrogator not using all-calls (e.g. MLAT) should also be able to insert any IC in the surveillance interrogation.

ACTION

TSG/12 is invited to:

a) review, modify, as necessary, and agree on the proposed changes to Annex 10 Volume IV.

1. INTRODUCTION

1.1 Multilateration

1.1.1 Some Mode S protocols such as the lockout protocol and the multisite data-link protocols use an Interrogator Code (IC) to differentiate interrogators in region of overlap.

1.1.2 Interrogators such as those used by multilateration systems do not use the lockout protocol nor the multisite data-link and therefore do not need to be allocated with a discrete IC to avoid interference in area of overlap.

1.1.3 However, Mode S interrogations must contain an Interrogator Identifier in the IIS or SIS fields even if the lockout protocol and the multisite data-link protocols are not used. This field could be used to track the interrogations from different multilateration systems operating in the same area without generating interferences; therefore, there are benefits to be able to choose different values for IIS.

1.2 Acquisition without coordination

1.2.1 Some interrogators, especially mobile interrogators, are not assigned unique, discrete ICs. Due to the mobile nature of these interrogators, avoiding overlap with another interrogator using the same code cannot be guaranteed. Therefore, the techniques in 3.1.2.5.2.1.4 and 3.1.2.5.2.1.5 of lockout override and supplemental acquisition are used to acquire targets.

1.2.2 Lockout override is currently limited to II=0 by 3.1.2.5.2.1.4.3. When a transponder receives a Mode S-only all-call that is using lockout override, the IC in the interrogation will not be a factor. The proposed changes in Section 2 include the allowance for an interrogator using lockout override to use any IC.

1.2.3 Supplemental acquisition of targets that cannot be acquired using lockout override is also currently limited to II=0. Supplemental acquisition is limited in duration and azimuth and operation using any IC should also be permitted.

2. DISCUSSION

2.1 Proposed changes to Annex 10 V4 3.1.2.1.5.1. The proposed changes remove the association of II=0 with supplemental acquisition. It is expected that further changes are forthcoming to 3.1.2.1.5.1.1 to remove the majority of references to the Mode A/C/S all-call. Therefore it is also expected that these changes are not necessary due to those expected changes, but they are included here for posterity and completeness.

3.1.2.1.5.1 *Intermode interrogation*

3.1.2.1.5.1.1 *Mode A/C/S all-call interrogation.* This interrogation shall consist of three pulses: P_1, P_3, and the long P_4 as shown in Figure 3-3. One or two control pulses (P_2 alone, or P_1 and P_2) shall be transmitted using a separate antenna pattern to suppress responses from aircraft in the side lobes of the interrogator antenna.

Note.— The Mode A/C/S all-call interrogation elicits a Mode A or Mode C reply (depending on the P_1-P_3 *pulse spacing) from a Mode A/C transponder because it does not recognize the* P_4 *pulse. A Mode S transponder recognizes the long* P_4 *pulse and responds with a Mode S reply. This interrogation was*

originally planned for use by isolated or clustered interrogators. Lockout for this interrogation was based on the use of II equals 0. The development of the Mode S subnetwork now dictates the use of a non-zero II code for communication purposes. ~~For this reason,~~ II equals 0 has been reserved for use in support of ~~a form of Mode S acquisition that uses stochastic/lockout override~~non-selective all-call lockout (~~3.1.2.5.2.1.4 and 3.1.2.5.2.1.5~~3.1.2.6.9.2). ~~The Mode A/C/S all-call cannot be used with full Mode S operation since II equals 0 can only be locked out for short time periods (3.1.2.5.2.1.5.2.1). This~~ The Mode A/C/S all-call interrogation cannot be used with stochastic/lockout override, since probability of reply cannot be specified.

3.1.2.1.5.1.1.1 Mode A/C/S all-call interrogations shall not be used on or after 1 January 2020.

Note 1.— The use of Mode A/C/S all-call interrogations does not allow the use of stochastic lockout override and therefore might not ensure a good probability of acquisition in areas of high density of flights or when other interrogators lockout transponder on II=0 for supplementary acquisition.

Note 2.— The replies to Mode A/C/S all-call interrogations will no longer be supported by equipment certified on or after 1 January 2020 in order to reduce the RF pollution generated by the replies triggered by the false detection of Mode A/C/S all-call interrogations within other types of interrogation.

2.2 Proposed changes to Annex 10 V4 3.1.2.5. The proposed changes allow use of any IC when performing acquisition based on lockout override. The changes also allow the use of any IC when performing supplemental acquisition. This therefore permits use of II=15 for mobile interrogators. If no IC is assigned, the default IC for supplemental acquisition is II=0. There is also additional clean-up of 3.1.2.5.2.1.2 (Interrogator Code definition) and 3.1.2.5.2.1.3.1. Finally, there is the removal of requirements on selected interrogations, as they are not appropriate in the all-call section. Any necessary requirements on selected interrogations are discussed in Section 2.3 of this paper.

3.1.2.5 INTERMODE AND MODE S ALL-CALL TRANSACTIONS

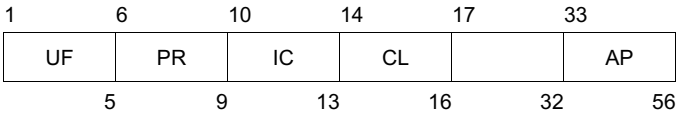
3.1.2.5.1 *INTERMODE TRANSACTIONS*

Note.— Intermode transactions permit the surveillance of Mode A/C-only aircraft and the acquisition of Mode S aircraft. The Mode A/C/S all-call interrogation allows Mode A/C-only and Mode S transponders to be interrogated by the same transmissions. The Mode A/C-only all-call interrogation makes it possible to elicit replies only from Mode A/C transponders. In multisite scenarios, the interrogator must transmit its identifier code in the Mode ~~S~~ S-only all-call interrogation. Thus, a pair of Mode S-only and Mode A/C-only all-call interrogations are used. The intermode interrogations are defined in 3.1.2.1.5.1 and the corresponding interrogation-reply protocols are defined in 3.1.2.4.

3.1.2.5.2 *MODE S-ONLY ALL-CALL TRANSACTIONS*

Note.— These transactions allow the ground to acquire Mode S aircraft by use of an interrogation addressed to all Mode S-equipped aircraft. The reply is via downlink format 11 which returns the aircraft address. The interrogation-reply protocols are defined in 3.1.2.4.

3.1.2.5.2.1 *Mode S-only all-call interrogation, uplink format 11*



The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	3.1.2.3.2.1.1
PR probability of reply	3.1.2.5.2.1.1
IC interrogator code	3.1.2.5.2.1.2
CL code label	3.1.2.5.2.1.3
spare — 16 bits	
AP address/parity	3.1.2.3.2.1.3

3.1.2.5.2.1.1 *PR: Probability of reply.* This 4-bit (6-9) uplink field shall contain commands to the transponder specifying the probability of reply to that interrogation (3.1.2.5.4). Codes are as follows:

0	signifies reply with probability of 1
1	signifies reply with probability of 1/2
2	signifies reply with probability of 1/4
3	signifies reply with probability of 1/8
4	signifies reply with probability of 1/16
5, 6, 7	not assigned
8	signifies disregard lockout, reply with probability of 1
9	signifies disregard lockout, reply with probability of 1/2
10	signifies disregard lockout, reply with probability of 1/4
11	signifies disregard lockout, reply with probability of 1/8
12	signifies disregard lockout, reply with probability of 1/16
13, 14, 15	not assigned.

3.1.2.5.2.1.2 *IC: Interrogator code.* This 4-bit (10-13) uplink field shall contain either the 4-bit interrogator identifier code (3.1.2.5.2.1.2.3) or the lower 4 bits of the 6-bit surveillance identifier code (3.1.2.5.2.1.2.4) depending on the value of the CL field (3.1.2.5.2.1.3).

3.1.2.5.2.1.2.1 **Recommendation.—** *It is recommended that whenever possible an interrogator should operate using a single ~~interrogator code~~IC.*

3.1.2.5.2.1.2.2 *The use of multiple ~~interrogator codes~~ICs by one interrogator.* An interrogator shall not interleave Mode S-only all-call interrogations using different ~~interrogator codes~~ICs.

Note.— An explanation of RF interference issues, sector size and impact on data link transactions is presented in the Aeronautical Surveillance Manual *(Doc 9924).*

3.1.2.5.2.1.2.3 *II: Interrogator identifier*. This 4-bit value shall define an interrogator identifier (II) code. These II codes ~~shall be~~are assigned to interrogators in the range from 0 to 15. ~~The II code value of 0 shall only be used for supplementary acquisition in conjunction with acquisition based on lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5).~~ When ~~two~~ multiple II codes are assigned to one interrogator only, one II code shall be used for full data link purposes.

Note 1.— Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.

Note 2.— Lockout on the II code value of 0 is used for non-selective all-call lockout (3.1.2.6.9.2). It is not used for multisite all-call lockout (3.1.2.6.9.1).

3.1.2.5.2.1.2.4 *SI: Surveillance identifier*. This 6-bit value shall define a surveillance identifier (SI) code. These SI codes ~~shall be~~are assigned to interrogators in the range from 1 to 63. The SI code value of 0 shall not be used. The SI codes shall be used with the multisite lockout protocols (3.1.2.6.9.1). The SI codes shall not be used with the multisite communications protocols (3.1.2.6.11.3.2, 3.1.2.7.4 or 3.1.2.7.7).

3.1.2.5.2.1.3 *CL: Code label.* This 3-bit (14-16) uplink field shall define the contents of the IC field.

Coding (in binary)

000	signifies that the IC field contains the II code
001	signifies that the IC field contains SI codes 1 to 15
010	signifies that the IC field contains SI codes 16 to 31
011	signifies that the IC field contains SI codes 32 to 47
100	signifies that the IC field contains SI codes 48 to 63

The other values of the CL field shall not be used.

3.1.2.5.2.1.3.1 *Surveillance identifier (SI) code capability report.* Transponders ~~which~~ that process ~~the~~ SI codes (3.1.2.5.2.1.2.4) shall report this capability by setting bit 35 of the MB field of the data link capability report (3.1.2.6.10.2.2) to 1 ~~in~~ (the surveillance identifier capability (SIC) subfield) ~~of the MB field of the data link capability report (3.1.2.6.10.2.2)~~.

3.1.2.5.2.1.4 *Operation based on lockout override*

Note 1.— The Mode S-only all-call lockout override provides the basis for acquisition of Mode S aircraft for interrogators that either have not been assigned an ~~unique~~ IC (II or SI code) ~~for full Mode S operation~~ or cannot ensure that their lockout region will not overlap with the lockout region of any other interrogator using the same IC, due to their mobile or transient operation. ~~(protected acquisition by ensuring that no other interrogator on the same IC can lock out the target in the same coverage area).~~

Note 2.— Lockout override ~~is possible~~ can be achieved using any ~~interrogator code~~IC by setting the probability of reply (3.1.2.5.2.1.1) code in the range of 8 – 12.

3.1.2.5.2.1.4.1 *Maximum Mode S-only all-call interrogation rate.* The maximum rate of Mode S-only all-call interrogations made by an interrogator using acquisition based on lockout override shall depend on the reply probability as follows:

a) for a reply probability equal to 1.0:

the smaller of 3 interrogations per 3 dB beam dwell or 30 interrogations per second;

b) for a reply probability equal to 0.5:

the smaller of 5 interrogations per 3 dB beam dwell or 60 interrogations per second; and

c) for a reply probability equal to 0.25 or less:

the smaller of 10 interrogations per 3 dB beam dwell or 125 interrogations per second.

Note.— These limits have been defined in order to minimize the RF pollution generated by such a method while keeping a minimum of replies to allow acquisition of aircraft within a beam dwell.

3.1.2.5.2.1.4.2 **Recommendation.—** *Passive acquisition without using all-call interrogations should be used in the place of lockout override.*

Note.— The Aeronautical Surveillance Manual *(Doc 9924) provides guidance on different passive acquisition methods.*

~~3.1.2.5.2.1.4.3~~ *Interrogator code.*

Note.— An interrogator may be assigned any II or SI code except SI equals 0 for use with lockout override. ~~*Field content for a selectively addressed interrogation used by an interrogator without an assigned interrogator code.* An interrogator~~ relying on Mode S only all-call interrogations to acquire ~~aircraft~~ that has not been assigned with a unique discrete~~an~~ interrogator code and is authorized to transmit ~~shall use the II code 0 to perform the selective interrogations. In this case, selectively addressed interrogations used in connection with acquisition using lockout override shall have interrogation field contents restricted as follows:~~

~~UF = 4, 5, 20 or 21~~
~~PC = 0~~
~~DI = 7~~
~~IIS = 0~~ ~~if performing supplementary acquisition as specified in 3.1.2.5.2.1.5~~
~~LOS = 0 except as specified in 3.1.2.5.2.1.5~~
~~TMS = 0~~

~~3.1.2.5.2.1.4.4 An interrogator that has not been assigned with a unique discrete interrogator code and is authorized to transmit using II code 0 shall not attempt to extract an air-initiated Comm-B message announced by DR = 1 or 3.~~

~~*Note. These restrictions permit surveillance transaction, GICB transaction and Comm-B broadcast extraction, but prevent the interrogation from making any changes to transponder multisite lockout or communications protocol states.*~~

3.1.2.5.2.1.5 *Supplementary acquisition* ~~*using II equals 0*~~

Note 1.— The acquisition technique defined in 3.1.2.5.2.1.4 provides rapid acquisition for most aircraft. Due to the probabilistic nature of ~~the process~~acquiring aircraft with a reduced reply probability (3.1.2.5.2.1.4.1), it may take many interrogations to acquire the last aircraft of a large set of aircraft in the same beam dwell and near the same range (termed a local garble zone). Acquisition performance is greatly improved for the acquisition of these aircraft through the use of limited selective lockout ~~using II equals 0~~.

Note 2.— Supplementary acquisition consists of locking out acquired aircraft ~~to II=0~~ followed by acquisition by means of the Mode S-only all-call interrogation ~~with II=0~~. Only the aircraft not yet acquired and not yet locked-out will reply resulting in an easier acquisition.

Note 3.— Supplementary acquisition used to augment operation based on lockout override (3.1.2.5.2.1.4) is possible using any IC. If no IC has been assigned, supplementary acquisition uses II equals 0 (3.1.2.5.2.1.5.3).

3.1.2.5.2.1.5.1 *Lockout within a beam dwell*

3.1.2.5.2.1.5.1.1 **Recommendation.—** *When ~~II equals 0~~ lockout is used to supplement the acquisition method described in 3.1.2.5.2.1.4, all aircraft within the beam dwell of the aircraft being acquired should be commanded to lock out ~~to II equals 0~~, not just those in the garble zone.*

Note.— Lockout of all aircraft in the beam dwell will reduce the amount of all-call fruit replies generated to the ~~II equals 0~~ all-call interrogations.

3.1.2.5.2.1.5.2 *Duration of lockout*

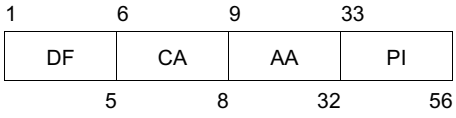
3.1.2.5.2.1.5.2.1 Interrogators performing supplementary acquisition ~~using II equals 0~~ shall perform acquisition by transmitting a lockout command for no more than two consecutive scans to each of the aircraft already acquired in the beam dwell containing the garble zone and shall not repeat it before 48 seconds have elapsed.

Note.— Minimizing the lockout time reduces the probability of conflict with the acquisition activities of a neighbouring interrogator that is ~~also using II equals 0~~using the same IC ~~for supplementary acquisition~~.

3.1.2.5.2.1.5.2.2 **Recommendation**.— *Mode ~~S~~ S-only all-call interrogations ~~with II=0~~ for the purpose of supplementary acquisition should take place ~~within a garble zone~~ over ~~no more than two consecutive scans or~~ a maximum of 18 seconds.*

3.1.2.5.2.1.5.3 *Interrogator code.* An interrogator authorized to transmit that has not been assigned an IC and is unable to ensure that its lockout region will not overlap with the lockout region of another interrogator using the same IC shall use II code 0 for supplemental acquisition.

3.1.2.5.2.2 *All-call reply, downlink format 11*



The reply to the Mode S-only all-call or the Mode A/C/S all-call interrogation shall be the Mode S all-call reply, downlink format 11. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
CA capability	3.1.2.5.2.2.1
AA address announced	3.1.2.5.2.2.2
PI parity/interrogator identifier	3.1.2.3.2.1.4

3.1.2.5.2.2.1 *CA: Capability.* This 3-bit (6-8) downlink field shall convey information on the transponder level, the additional information below, and shall be used in formats DF = 11 and DF = 17.

Coding

0 signifies Level 1 transponder (surveillance only), and no ability to set CA code 7 and either airborne or on the ground
1 reserved
2 reserved
3 reserved
4 signifies Level 2 or above transponder and ability to set CA code 7 and on the ground
5 signifies Level 2 or above transponder and ability to set CA code 7 and airborne
6 signifies Level 2 or above transponder and ability to set CA code 7 and either airborne or on the ground
7 signifies the DR field is not equal to 0 or the FS field equals 2, 3, 4 or 5, and either airborne or on the ground

When the conditions for CA code 7 are not satisfied, aircraft with Level 2 or above transponders:

a) that do not have automatic means to set the on-the-ground condition shall use CA code 6; and

b) with automatic on-the-ground determination shall use CA code 4 when on the ground and 5 when airborne.

Data link capability reports (3.1.2.6.10.2.2) shall be available from aircraft installations that set CA code 4, 5, 6 or 7.

Note.— CA codes 1 to 3 are reserved to maintain backward compatibility.

3.1.2.5.2.2.2 *AA: Address announced.* This 24-bit (9-32) downlink field shall contain the aircraft address which provides unambiguous identification of the aircraft.

3.1.2.5.3 *Lockout protocol.* The all-call lockout protocol defined in 3.1.2.6.9 shall be used by the interrogator with respect to an aircraft once the address of that specific aircraft has been acquired by an interrogator provided that:

— the interrogator is using an IC code different from zero; and

— the aircraft is located in an area where the interrogator is authorized to use lockout.

Note 1.— Following acquisition, a transponder is interrogated by discretely addressed interrogations as prescribed in 3.1.2.6~~,~~ and 3.1.2.7 ~~and 3.1.2.8~~ and the all-call lockout protocol is used to inhibit replies to further all-call interrogations.

Note 2.— Regional IC allocation bodies may define rules limiting the use of selective interrogation and lockout protocol (e.g. no lockout in defined limited area, use of intermittent lockout in defined areas, and no lockout of aircraft not yet equipped with SI code capability).

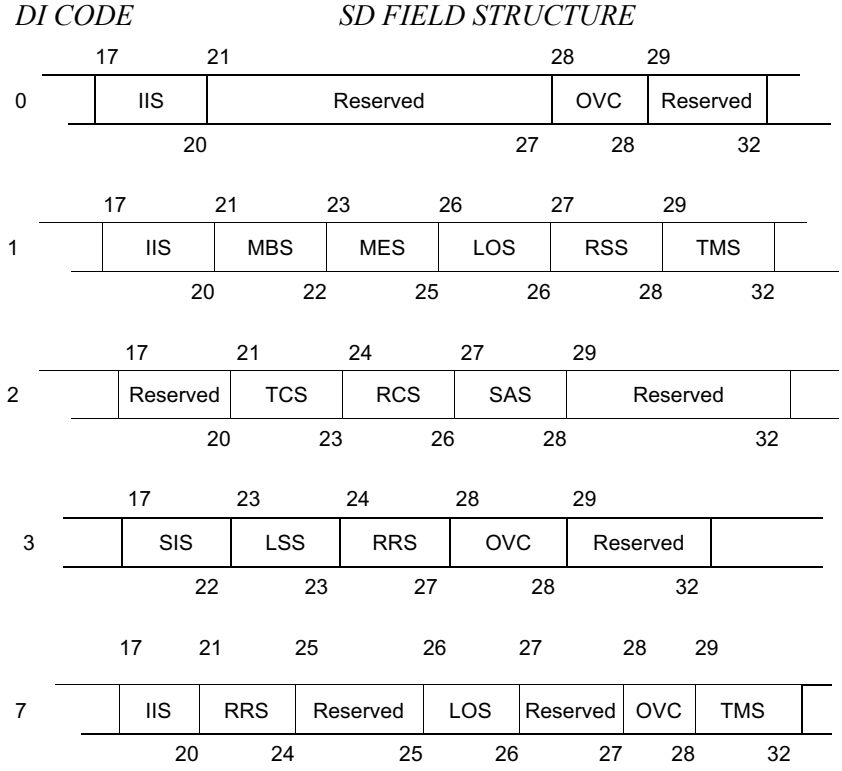
3.1.2.5.4 *Stochastic all-call protocol.* The transponder shall execute a random process upon acceptance of a Mode S-only all-call with a PR code equal to 1 to 4 or 9 to 12. A decision to reply shall be made in accordance with the probability specified in the interrogation. A transponder shall not reply if a PR code equal to 5, 6, 7, 13, 14 or 15 is received (3.1.2.5.2.1.1).

Note.— The random occurrence of replies makes it possible for the interrogator to acquire closely spaced aircraft, replies from which would otherwise synchronously garble each other.

2.3 Proposed changes to Annex 10 V4 3.1.2.6.1.4. Proposed changes make the IIS and SIS fields more generic and add notes to clarify that interrogators not using all-calls or lockout protocol for acquisition may use any IC in the IIS and SIS fields.

3.1.2.6.1.4 *SD: Special designator.* This 16-bit (17-32) uplink field shall contain control codes which depend on the coding in the DI field.

Note.— The special designator (SD) field is provided to accomplish the transfer of multisite, lockout and communications control information from the ground station to the transponder.



3.1.2.6.1.4.1 *Subfields in SD.* The SD field shall contain information as follows:

a) If DI = 0, 1 or 7:

IIS, the 4-bit (17-20) interrogator identifier subfield shall contain ~~an~~ the ~~assigned~~ identifier code of the interrogator (3.1.2.5.2.1.2.3).

Note.— The IIS is intended to match the II code used by the interrogator in the Mode S-only all-call interrogation (3.1.2.5.2.1). Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol, or multisite data-link protocol can use any IC in the IIS fields of their selective interrogations without coordination with neighbouring systems. The use of coordinated values differentiates interrogations transmitted by the different systems operating in the same area and facilitates the understanding of their respective contribution to the 1090 MHz environment.

b) If DI = 0:

bits 21-27 and 29-32 are not assigned.

c) If DI = 1:

MBS, the 2-bit (21, 22) multisite Comm-B subfield shall have the following codes:

0 signifies no Comm-B action
1 signifies air-initiated Comm-B reservation request (3.1.2.6.11.3.1)
2 signifies Comm-B closeout (3.1.2.6.11.3.2.3)
3 not assigned.

MES, the 3-bit (23-25) multisite ELM subfield shall contain reservation and closeout commands for ELM as follows:

0 signifies no ELM action
1 signifies uplink ELM reservation request (3.1.2.7.4.1)
2 signifies uplink ELM closeout (3.1.2.7.4.2.8)
3 signifies downlink ELM reservation request (3.1.2.7.7.1.1)
4 signifies downlink ELM closeout (3.1.2.7.7.3)
5 signifies uplink ELM reservation request and downlink ELM closeout
6 signifies uplink ELM closeout and downlink ELM reservation request
7 signifies uplink ELM and downlink ELM closeouts.

RSS, the 2-bit (27, 28) reservation status subfield shall request the transponder to report its reservation status in the UM field. The following codes have been assigned:

0 signifies no request
1 signifies report Comm-B reservation status in UM
2 signifies report uplink ELM reservation status in UM
3 signifies report downlink ELM reservation status in UM.

d) If DI = 1 or 7:

LOS, the 1-bit (26) lockout subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in IIS. LOS set to 0, shall be used to signify that no change in lockout state is commanded.

TMS, the 4-bit (29-32) tactical message subfield shall contain communications control information

used by the data link avionics.

e) If DI = 7:

RRS, the 4-bit (21-24) reply request subfield in SD shall give the BDS2 code of a requested Comm-B reply.

Bits 25 and 27 are not assigned.

f) If DI = 2:

TCS, the 3-bit (21-23) type control subfield in SD shall control the extended squitter airborne and surface format types reported by the transponder and its response to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations. The following codes have been assigned:

0 signifies no surface format types or reply inhibit command
1 signifies surface format types for the next 15 seconds (see 3.1.2.6.1.4.2)
2 signifies surface format types for the next 60 seconds (see 3.1.2.6.1.4.3)
3 signifies cancel surface format types and reply inhibit commands
4-7 reserved.

The transponder shall be able to accept a new command even though a prior command has not as yet timed out.

RCS, the 3-bit (24-26) rate control subfield in SD shall control the squitter rate of the transponder when it is reporting the extended squitter surface type formats. This subfield shall have no effect on the transponder squitter rate when it is reporting the extended squitter airborne type formats. The following codes have been assigned:

0 signifies no surface extended squitter rate command
1 signifies report high surface extended squitter rate for 60 seconds
2 signifies report low surface extended squitter rate for 60 seconds
3-7 reserved.

Note 1.— The definition of high and low extended squitter rates is given in 3.1.2.8.6.4 and applies to the surface position, aircraft identification and category, and the operational status messages.

Note 2.— As stated in 3.1.2.8.5.2 d), acquisition squitters are transmitted when surface type format extended squitters are not being transmitted.

SAS, the 2-bit (27-28) surface antenna subfield in SD shall control the selection of the transponder diversity antenna that is used for (1) the extended squitter when the transponder is reporting the surface type formats, and (2) the acquisition squitter when the transponder is reporting the on-the-ground status. This subfield shall have no effect on the transponder diversity antenna selection when it is reporting the airborne status. The following codes have been assigned:

0 signifies no antenna command
1 signifies alternate top and bottom antennas for 120 seconds
2 signifies use bottom antenna for 120 seconds
3 signifies return to the default.

Note.— The top antenna is the default condition (3.1.2.8.6.5).

g) If DI = 3:

SIS, the 6-bit (17-22) surveillance identifier subfield in SD shall contain ~~an assigned~~the surveillance identifier code of the interrogator (3.1.2.5.2.1.2.4).

Note.— The SIS is intended to match the SI code used by the interrogator in the Mode S-only all-call interrogation (3.1.2.5.2.1). Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol, or multisite data-link protocol can use any IC in the SIS fields of their selective interrogations without coordination with neighbouring systems. The use of coordinated values differentiates interrogations transmitted by the different systems operating in the same area and facilitates the understanding of their respective contribution to the 1090 MHz environment.

LSS, the 1-bit (23) lockout surveillance subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in SIS. If set to 0, LSS shall signify that no change in lockout state is commanded.

RRS, the 4-bit (24-27) reply request subfield in SD shall contain the BDS2 code of a requested GICB register.

Bits 29 to 32 are not assigned.

h) If DI=4, 5 or 6 then the SD field has no meaning and shall not impact other transaction cycle protocols. These DI codes remain reserved until future assignment of the SD field.

i) If DI = 0, 3 or 7:

In addition to the requirements provided above, the "SD" shall contain the following:

"OVC": The 1-bit (bit 28) "overlay control" subfield in "SD" is used by the interrogator to command that the data parity ("DP" 3.1.2.3.2.1.5) be overlaid upon the resulting reply to the interrogation in accordance with paragraph 3.1.2.6.11.2.5.

3.1.2.6.1.4.2 *TCS subfield equal to one (1) in the SD field for extended squitters*. When the TCS subfield in the SD field is set equal to one (1), it shall signify the following:

a) broadcast of the extended squitter surface formats, including the surface position message (3.1.2.8.6.4.3), the identification and category message (3.1.2.8.6.4.4), the aircraft operational status message (3.1.2.8.6.4.6) and the aircraft status message (3.1.2.8.6.4.6) for the next 15 seconds at the appropriate rates on the top antenna for aircraft systems having the antenna diversity capability, except if otherwise specified by SAS (3.1.2.6.1.4.1 f));

b) inhibit replies to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations for the next 15 seconds;

c) broadcast of acquisition squitters as per 3.1.2.8.5 using antenna as specified in 3.1.2.8.5.3 a);

d) does not impact the air/ground state reported via the CA, FS and VS fields;

e) discontinue broadcast of the extended squitter airborne message formats; and

f) broadcast of the extended squitter surface formats at the rates according to the TRS subfield unless commanded to transmit at the rates set by the RCS subfield.

3.1.2.6.1.4.3 *TCS subfield equal to two (2) in the SD field for extended squitters.* When the TCS subfield in the SD field is set equal to two (2), it shall signify the following:

a) broadcast of the extended squitter surface formats, including the surface position message (3.1.2.8.6.4.3), the identification and category message (3.1.2.8.6.4.4), the aircraft operational status message (3.1.2.8.6.4.6) and the aircraft status message (3.1.2.8.6.4.6) for the next 60 seconds at the appropriate rates on the top antenna for aircraft systems having the antenna diversity capability, except if otherwise specified by SAS (3.1.2.6.1.4.1 f));

b) inhibit replies to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations for the next 60 seconds;

c) broadcast of acquisition squitters as per 3.1.2.8.5 using antenna as specified in 3.1.2.8.5.3 a);

d) does not impact the air/ground state reported via the CA, FS and VS fields;

e) discontinue broadcast of the extended squitter airborne message formats; and

f) broadcast of the extended squitter surface formats at the rates according to the TRS subfield unless commanded to transmit at the rates set by the RCS subfield.

3.1.2.6.1.5 *PC and SD field processing.* When DI = 1, PC field processing shall be completed before processing the SD field.

2.4 Proposed changes to Annex 10 V4 3.1.2.6.11.3. The proposed changes include restrictions on air-initiated Comm-B extraction by interrogators that have not been assigned an IC that is ensured to not overlap with another interrogator (previously referred to as “unique discrete”). This requirement was previously in 3.1.2.5.2.1.4.3, though worded differently.

3.1.2.6.11.3 *Air-initiated Comm-B*

3.1.2.6.11.3.1 *General protocol.* The transponder shall announce the presence of an air-initiated Comm-B message with the insertion of code 1 in the DR field. To extract an air-initiated Comm-B message, the interrogator shall transmit a request for a Comm-B message reply in a subsequent interrogation with RR equal to 16 and, if DI equals 7, RRS must be equal to 0 (3.1.2.6.11.3.2.1 and 3.1.2.6.11.3.3.1). Receipt of this request code shall cause the transponder to transmit the air-initiated Comm-B message. If a command to transmit an air-initiated Comm-B message is received while no message is waiting to be transmitted, the reply shall contain all ZEROs in the MB field.

The reply that delivers the message shall continue to contain code 1 in the DR field. After a Comm-B closeout has been accomplished, the message shall be cancelled and the DR code belonging to this message immediately removed. If another air-initiated Comm-B message is waiting to be transmitted, the transponder shall set the DR code to 1, so that the reply contains the announcement of this next message.

Note.— The announcement and cancellation protocol ensures that an air-initiated message will not be lost due to uplink or downlink failures that occur during the delivery process.

An interrogator that has either not been assigned an IC or cannot ensure that its interrogation region will not overlap with the interrogation region of another interrogator using the same IC shall not attempt to extract an air-initiated Comm-B message announced by DR = 1 or 3.

2.5 Proposed changes to Annex 10 V4 3.1.2.11. The proposed changes add context to the lockout coordination section and change the section header from "ground interrogator" to "SSR Mode S interrogator" to be all inclusive.

3.1.2.11 ESSENTIAL SYSTEM CHARACTERISTICS OF THE ~~GROUND~~ SSR MODE S INTERROGATOR

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3.1.2.11.6 *Lockout coordination.* A Mode S interrogator shall not be operated using all-call lockout until coordination has been achieved with all other operating Mode S interrogators having any overlapping coverage volume in order to ensure that no interrogator can be denied the acquisition of Mode S-equipped aircraft. If coordination is not possible due to system designs (for example, a mobile interrogator), the interrogator shall either use passive means of acquisition or operate using lockout override (3.1.2.5.2.1.4) with supplementary acquisition (3.1.2.5.2.1.5).

Note 1.— This coordination may be via ground network or by the allocation of ~~interrogator identifier (II) codes~~ ICs and will involve regional agreements where coverage overlaps international boundaries.

Note 2.— Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol, or multisite data-link protocol can use any IC value in the IIS or SIS fields of their selective interrogations without a need for coordination with neighbouring systems.

3.1.2.11.7 *MOBILE INTERROGATORS*

Recommendation.— *Mobile interrogators should acquire, whenever possible, Mode S aircraft through the reception of squitters.*

Note.— Passive squitter acquisition reduces channel loading and can be accomplished without the need for coordination.

2.6 Proposed changes to Doc 9924 Appendix H to allow lockout override on any IC and include details on supplementary acquisition.

2. CONCEPTS FOR MODE S ACQUISITION WITHOUT LOCKOUT

2.1 Mode S acquisition using lockout override

2.1.1 Operational concept

2.1.1.1 Certain interrogators (e.g. mobile military interrogators) may not be in a position to have an assigned II or SI code in order to perform normal Mode S surveillance. A technique for performing Mode S acquisition using lockout override that does not require an assigned IC is described in this section.

2.1.1.2 An operational concept for Mode S acquisition using lockout override is defined as follows:

a) Routine aircraft surveillance is performed by these interrogators using Mode A/C, primary radar surveillance, or other means. For Mode A/C, monopulse processing must be used for having a lower interrogation rate. The channel time now available is used for Mode S acquisition;

b) On each scan, this type of interrogator schedules a number of Mode S-only all-call interrogations, followed by a listening interval appropriate for the operating range. These interrogations contain a lockout override code that commands Mode S transponders to respond to the interrogation regardless of their lockout state. The resulting synchronous garble is managed through the use of PR = 10 to 12 in the Mode S-only all-call interrogation. These codes command lockout override, together with a reduced probability of reply;

c) Every ungarbled Mode S all-call reply is processed and correlated in range and azimuth to the corresponding Mode A/C or primary radar track. The all-call reply contains the 24-bit aircraft address. This address is used in Mode S discretely addressed interrogations to obtain any supplemental information available from that aircraft. These discretely addressed interrogations may contain any IC ~~equal to ZERO (0)~~ but do not contain any lockout commands. The discrete surveillance replies contain Mode C and Mode A codes which can also be used as further correlation criteria with a Mode A/C track. The interrogator has not modified in any way the lockout state of the aircraft as established by neighbouring Mode S interrogators using the multisite lockout protocols;

d) The 24-bit aircraft address is stored in the track file and is used for a subsequent update of this supplemental information;

e) The Mode S acquisition status of every aircraft in track is maintained in the track file, with one of the three following characteristics:

1) aircraft address acquired;

2) confirmation that the aircraft is not Mode S-equipped, since a prescribed number of interrogations has not resulted in an error-free reply reception or a Mode S preamble detection; or

3) Mode S acquisition in process; and

f) In order to minimize all-call FRUIT, all-call interrogations are only transmitted in beam dwells containing aircraft that are currently in the acquisition process.

2.1.2 Control of synchronous garble

2.1.2.1 The above operational concept for Mode S acquisition is based on the use of the lockout override feature. As the name implies, a Mode S-only all-call interrogation carries a code (PR = 8 to 12) that instructs the transponder to reply to this all-call regardless of its lockout state. Lockout override would be of limited use by itself since such transmissions would likely result in synchronously garbled Mode S all-call replies from aircraft close in slant range and within the same beam dwell as the aircraft of interest. The synchronous garble range for a Mode S all-call reply is 9.6 km (5.2 NM).

2.1.2.2 Mode S includes another feature known as “stochastic acquisition” that should be used with lockout override. Stochastic acquisition overcomes synchronous all-call garble by commanding the transponder (via a code in the all-call interrogation, PR = 10 to 12) to respond with a probability less than unity. Available probabilities are 1/4, 1/8 and 1/16. A reply probability of less than one reduces the total number of replies from a set of aircraft in garble range. This increases the likelihood of receiving a single ungarbled reply from an unacquired aircraft. Stochastic acquisition makes it possible to acquire a Mode S aircraft, even in relatively dense environments.

2.1.2.3 The performance of stochastic acquisition as a function of the number of aircraft in a garble zone and the probability used is presented in Table H-1. A summary of the performance to be expected with this technique is presented in Table H-2. The rows in Table H-2 indicate the number of aircraft in the garble

zone defined by the beamwidth, and the 9.6 km (5.2 NM) garble zone for the Mode S all-call reply. It should be noted that having more than ten aircraft in the defined zone is quite rare. The columns indicate the maximum and average number of interrogations needed for 99 per cent probability of acquisition.

2.1.2.4 If an interrogator is unable to acquire all aircraft in a garble zone using stochastic acquisition, supplementary acquisition may be employed. Supplementary acquisition includes temporarily locking out all aircraft within the beam dwell of the unacquired aircraft. If the interrogator has been assigned an II or SI code, then that code may be used for supplementary acquisition. If the interrogator has not been assigned an II or SI code and coordination with other interrogators is not possible, II equals 0 should be used. Lockout as part of supplementary acquisition may be used for no more than two consecutive scans to each aircraft already acquired in the beam dwell containing the garble zone and may not be repeated within 48 seconds. It is important to minimize the lockout time to reduce the probability of conflict with neighbouring interrogators using the same IC.

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2.1.5 Adaptive technique for reduced acquisition time

2.1.5.1 *Need for an adaptive technique*

The simulation results show that while rapid acquisition is provided by lockout override for most aircraft, it may take a long time to acquire all aircraft in a high density environment. Acquisition performance can, however, be improved by the use of supplementary acquisition via selective lockout.

2.1.5.2 *Use of II = 0*

2.1.5.2.1 The development of the Mode S subnetwork algorithms has greatly limited the utility of II code zero. The subnetwork communication protocols require the use of a non-zero II code in order to support downlink routing. Thus II = 0 will not be used when Mode S data link is used with the subnetwork services, even in areas of no overlapping sensor coverage.

2.1.5.2.2 Given that II = 0 will not be used in the most dense areas, it would seem that II = 0 could be eliminated for normal acquisition use without restricting Mode S operations.

2.1.5.3 *Adaptive acquisition*

2.1.5.3.1 For acquiring the last of the aircraft in a garble zone, an adaptive technique ~~using II = 0~~ operates as follows:

a) all of the acquired aircraft in the beam dwell of the garble zone containing the unacquired aircraft are discretely interrogated and locked out ~~to II = 0~~;

b) during the following scan, all-call interrogations are transmitted ~~using II = 0~~, without lockout override, such that only the unacquired aircraft within the beam dwell will respond; and

c) transponders will unlock ~~to II = 0,~~ 18 seconds after the last lockout command.

2.1.5.3.2 The reduced garble density will lead to rapid acquisition of the unacquired aircraft, or a determination that it is not Mode S-equipped. Since lockout is used only temporarily and selectively, only a minimum of coordination is required with neighbouring interrogators using lockout override to avoid conflict ~~in the use of lockout to II = 0~~.

2.1.5.3.3 While this adaptive technique is often performed using II=0, it is possible using any II or SI code. If an interrogator has been assigned a non-unique IC (e.g., two mobile interrogators assigned the same IC), it may be possible to use that IC for supplementary acquisition. Coordination is recommended to ensure that any interference between interrogators using the same IC is minimized. Interrogators that have not been assigned an IC and cannot ensure they will not overlap with another interrogator using the same IC should use II=0 for supplementary acquisition.

2.7 Proposed changes to Doc 9924 Appendix M. The proposed changes are based primarily on those agreed upon by the TSG in ASWG TSG WP 10-21R2.

4. MLAT

4.1 Multilateration (MLAT) ~~is basically a passive system but it~~systems may use interrogations to achieve a certain level of performance~~. Active WAM systems can be used in approach and en route environments. H~~; however, care must be exercised to limit ~~the~~ interrogations, primarily to minimize transponder occupancy. ~~In such cases, s~~Selective interrogations transmitted by active systems have ~~the dominant~~ an important effect on ~~the~~ transponder availability because of the use of omnidirectional antennas. MLAT systems do not use Mode S all-call interrogations, lockout protocol, or multisite protocol. Therefore, they can use any IC in the IIS or SIS field of their selective interrogations, as it will not interfere with other interrogators using these protocols.

4.2 Significant levels of ~~ACAS~~ interrogations may reduce the transponder availability to a point that roll-call retries start to become a significant factor. However, this will be mitigated by a dynamic ~~active~~ WAM, which could abate roll-call in the presence of ~~ACAS~~ passive reception of altitude reports.

3. **ACTION BY THE MEETING**

3.1 TSG/12 is invited to:

a) review, modify, as necessary, and agree on the proposed changes to Annex 10 Volume IV.

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